Analysis of human thermal conditions in winter for different urban structures in Erzurum

Hasan YILMAZ

Hasan Yılmaz[1*] Nalan D. Yıldız[1] Uğur Avdan[2] Ahmet Koç[1] Andreas Matzarakis[3]

[1]Ataturk University, Faculty of Architecture and Design, Dept. of Landscape Architecture, 25240, Erzurum/ Turkey
[2] Anadolu University, Research Institute of Earth and Space Sciences, Eskişehir /Turkey

[3]Albert-Ludwigs-University of Freiburg, D-79085Freiburg,Germany

Healthy urban planning and modelling are necessary for sustainable urbanization. This study was carried out in the city of Erzurum, which is located at a 2000 – m altitude and the coldest city in Turkey and where urban transformation projects have been implemented in the last few years. Four different parts of the urban areas are decided for the case study to be (1) Erzurum city center, (2) Botanic garden of Ataturk University, (3) Yenisehir and (4) Dadaskent. PET and SVF were measured in these areas and measurements were conducted at 9:00, 12:00, 15:00 and 18:00, peak hours in which people are using outdoor in winter months (December- January - February). Life comfort, which is the issue tried to be measured in this study, is extremely important the cities facing long winter period. In addition to PET and SVF, Landsat satellite images are used for the measurement and in this process; different categories are defined for the determination of alteration in the heat islands. In conclusion, related to the structural and plant design in urban areas, design based suggestions are made to increase urban comfort.

Keywords: urban design, PET, Winter comfort, SVF, Thermal Band

1. INTRODUCTION

New approaches for healthy and sustainable environment have been experienced in urban areas in the scope of landscape planning and design. Among such approaches, climate balanced planning includes thermal comfort studies even though they are new for Turkey. Climatic change and UHI may change local, regional, national and global scale climatic parameters (Oke et al. 1991,Oke 1993; Kalnay and Cai 2003).

The overall importance of the PET in outdoor thermal comfort has been given special attention in this process. There are so many studies in the literature using PET values. The number of studies carried out to determine the causes and effects of urban land - uses on urban microclimate and ecosystem is quite limited in Erzurum (Yilmaz et al. 2007, Yilmaz et al 2008, Yilmaz et al 2010, Irmak et al. 2013, Yilmaz et al 2013, Bulgan et al 2014). The SVF values are used in different studies for the thermal comfort analysis. Urban outdoor thermal environment is impacted by trees and man made objects, streets (w/h), heating and street orientation. SVF is used in urban areas (Lin et al. 2010, Matuscheck and Matzarakis, 2011; Herrmann and Matzarakis, 2012; Correa et al. 2012, Yan et al. 2014, Yavas et al. 2014).

The aim of present study is to plan healthier, more liveable and thermally more comfortable areas for urban people and produce data for the same aim. It is targeted to gain experience to take the advantages of urban transformation works in Erzurum. In Erzurum, chosen to be study area, present location areas were evaluated and SVF measurements were conducted at the points on main arteries thought to represent the areas best. Roads are the areas making accessibility possible for urban people in urban areas in daily life. For people using these areas security and thermal comfort are extremely important. Winter season PET calculations were conducted in December, January and

February in 2013 and 2014. It was emphasized that climate and its effects should be taken into consideration for planning roads in addition to other factors. It was also targeted to attract planners and designers' attention to bioclimatic comfort in order to create more comfortable areas. Importance of thermal comfort is emphasized in urban planning. Data obtained from Erzurum Meteorology Service for the study period were used to calculate PET through RayMan model (Matzarakis et al. 2007, 2010).

2. MATERIAL AND METHOD

2.1. Material

Material of the study includes the roads used most densely in Erzurum city centre. For this aim, measurements were conducted at four different road axes in Erzurum.

Study area is located in the eastern part of Turkey at an elevation of 1850 m. In the city, a harsh continental climate is prevalent, which means winters are long and extremely cold. This station (at an elevation of 1758m and a location of 39º.57N and 41º.10E), considered as the representative of a rural area, is in the Airbase area lying about 7 km from the city. The Airbase is surrounded by the vast open area in all directions. There are no buildings or human activities around the station except for the cultivated area which is 4km from the station and where plants that do not need watering are grown. Data obtained from Erzurum Meteorology Service for the study period were used to calculate PET through RayMan model. Winter season PET calculations were conducted in December, January and February in 2013 and 2014. The location of the measurement stations and SVF points for the data used in this study is shown in Figure 1.

2.2. Method

In this study, Erzurum city centre are decided for climatic analysis. For those areas, Sky View Factors (SVF) and PET values are calculated and compared with the data obtained from Meteorological Station. The location of the measurement stations and SVF points for the data used in this study is shown in Figure 1.

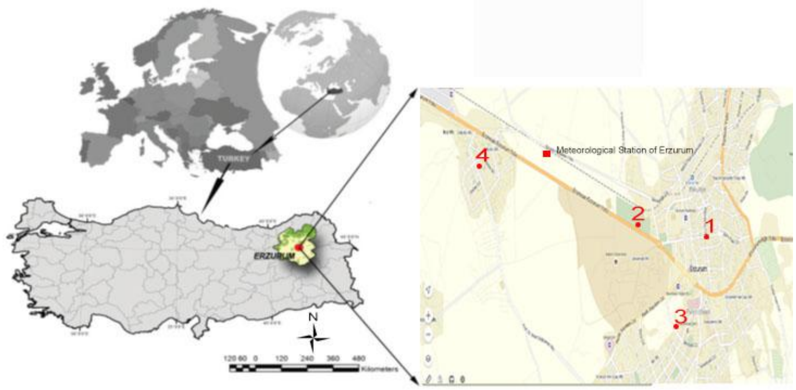


Figure 1. Study areas (1) Erzurum city center, (2) Botanic garden of Ataturk University, (3) Yenisehir and (4) Dadaskent and meteorology station

2.2.1.SVF Analysis:

The sky view factor (SVF), expresses the ratio between radiation received by a planar surface and that from the entire hemispheric radiating. The SVF is a dimensionless value between 0 and 1 and approaches unity in perfectly flat terrain, whereas locations with obstructions such as buildings and trees will cause the SVF to decrease proportionally (Oke 1993; Gulten 2007). The SVF is, in this sense, a measure of the openness of the sky to radiative transport in relation to a specific location, where a value of 0 (complete obstruction) means that all outgoing radiation will be intercepted by obstacles and a value of 1 (no obstruction) means that all radiation will propagate freely to the sky (Brown and Grimmond 2001, Souza et al. 2003, Gulten 2007). Four different main road and pavement have been chosen, fish-eye photos were taken about 1.5 m above of each point by high-definition camera integrated with fisheye lens by three repetitions in different four stations. The relation between the variables was evaluated by the method of ordination analysis via the computer program CANOCO version 4.5 (Ter Braak, 1991). The relation between Sky view factors (SVF) and data for height and diameter of plant trends near-linear. When there is such this trend, RDE (Redundancy Analysis) analysis method is preferred (Ter Braak, 1991) in the ordination analysis, so these techniques were used in this study

2.2.2. RayMan;

Bioclimatic comfort is the climatic conditions where people consume less energy and feel themselves healthy and dynamic (Fanger 1970). Winter season data (December, January and February) of 2013 and 2014 were used for the study and calculation considering the most densely active hours for people 9, 12, 15 and 18. Rayman 2.1 pro model was used for the calculation of PET considering thermophysiological conditions; age, gender, height, weight clothing insulation, physical activity and position (Matzarakis et al. 2006; Gulyas et al. 2006) and air temperature (Ta-°C), wind velocity V (m/s), relative humidity (RH-%), cloudiness (N-octas) or radiation (W/m²) (Höppe 1999; Matzarakis et al. 1999, Matzarakis et al. 2010). Wind was used in the calculations by reducing data from 2 m to 1.1 m.

RESULTS

In the present study, thermal comfort conditions were evaluated over pedestrian sidewalks. Pedestrian comfort and security may be lessened due to the icing on the roads in winter. SVF measurements were conducted on the road axes densely used in Erzurum city centre. Axes were chosen among the most densely used roads. Three different points were selected to make measurements. Photos tried to be taken from the empty points on main axis including building and tree. Results are presented below.

Station 1 is Cumhuriyet Street most densely used main-street of the city centre. Since it is the commercial centre of the city, it is used most densely by youths and other people on foot or by car. Measurements were taken from the points with two side buildings, one tree and one building and empty Width of the road is between 17 and 28 m (Figure 2). At the point with coniferous tree SVF was found to be the largest with 0.052.

Station 2 is on the main axis at Ata Botanical Garden of Atatürk University, 2 km away from city centre and functioning as green heart. Measurements were taken from three different points. The highest SVF value was found at this point with 0.951. At the point covered with coniferous trees, SVF is lower with 0.174 (Figure 3).

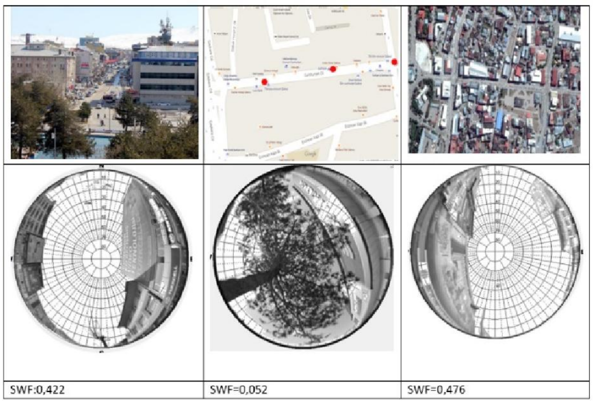


Figure 2. SVF on Cumhuriyet Street

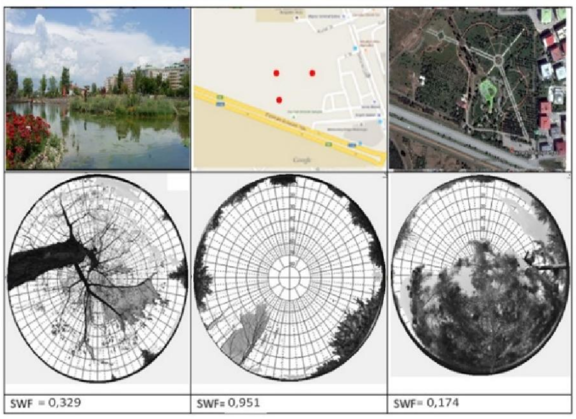
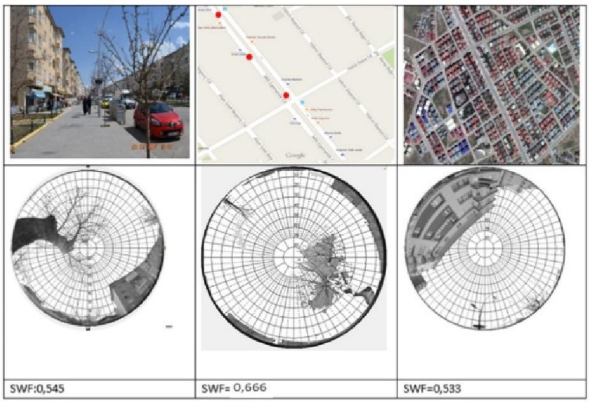


Figure 3. Atatürk University Ata Botanical Garden

Station 3 is on the main axis of Dadaskent neighbourhood constructed in 1990s functioning as a satellite city. Width of the road is 40 m. SVF values are very close to each other (Figure 4).

Station 4 is Yenisehir neighbourhood constructed in 1980s and measurement points are given in Figure 5. Both the settlement area and the sidewalks where measurement points are located have been designed conveniently design and planning principles. SVF values are between 0.430 and 0.882 (Figure 5). Width of the road is 40 m.



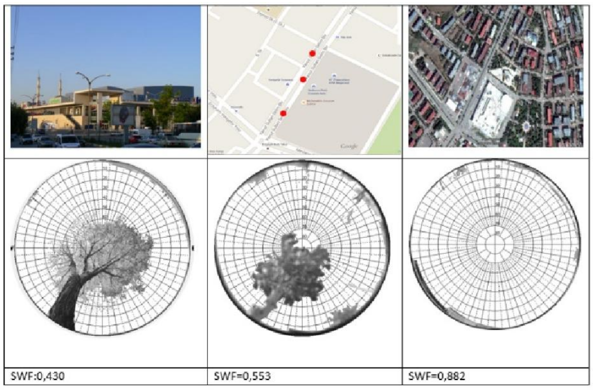
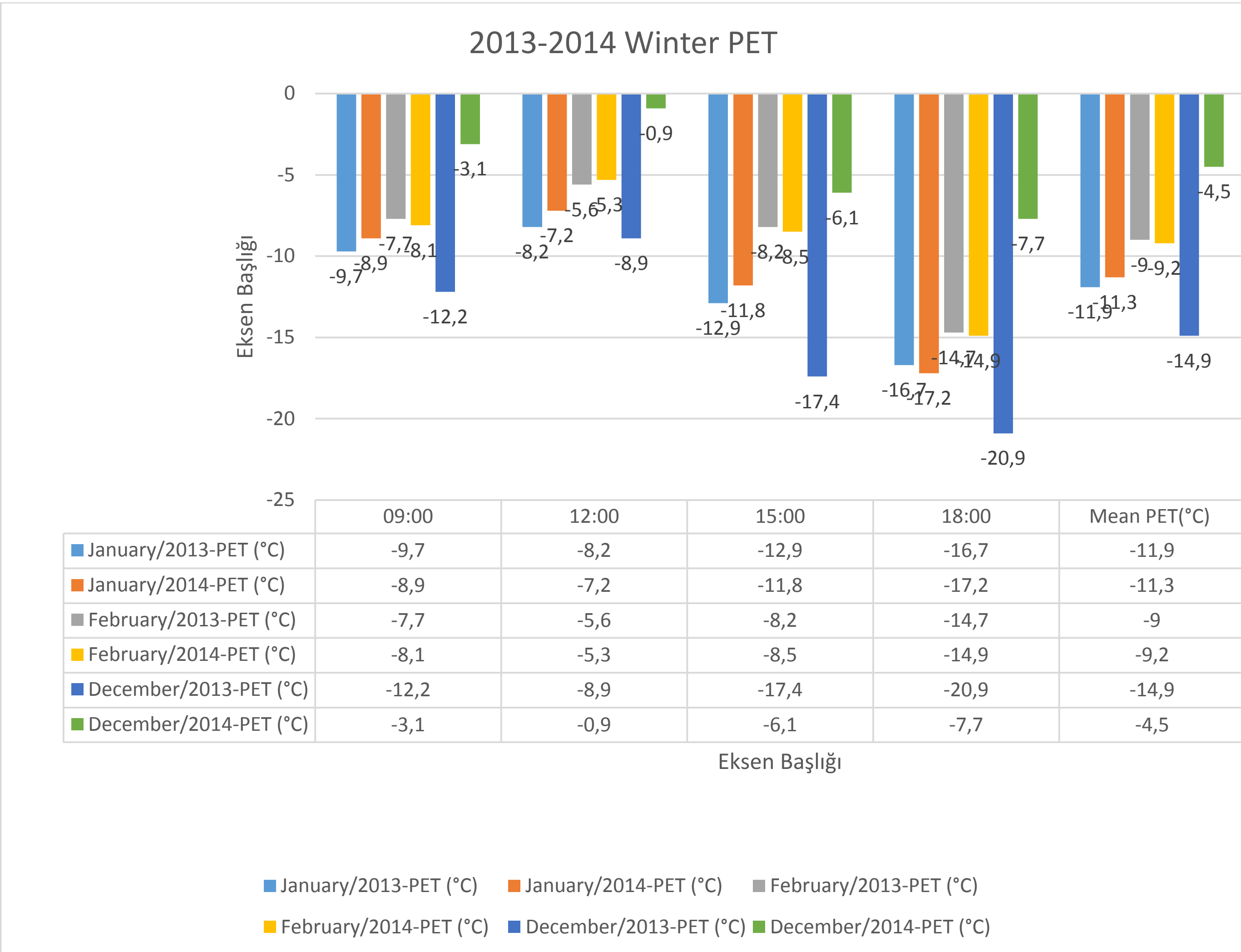


Figure 4. Dadaskent neighbourhood and measurements on main axis
Figure 5. Yenişehir neighbourhood SVF analysis

All climate parameters were obtained from the General Directorate of Meteorology Airport Station in Erzurum which is also the reference station of this study. Erzurum city winter data for 2013 and 2014 were used to compute daily PET values. Analysis of PET thermal index is shown in Fig. 6.



	09:00	12:00	15:00	18:00	Mean PET(°C)
January/2013-PET (°C)	-9,7	-8,2	-12,9	-16,7	-11,9
January/2014-PET (°C)	-8,9	-7,2	-11,8	-17,2	-11,3
February/2013-PET (°C)	-7,7	-5,6	-8,2	-14,7	-9
February/2014-PET (°C)	-8,1	-5,3	-8,5	-14,9	-9,2
December/2013-PET (°C)	-12,2	-8,9	-17,4	-20,9	-14,9
December/2014-PET (°C)	-3,1	-0,9	-6,1	-7,7	-4,5

Figure 6. PET values for winter months 2013-2014.

Conclusion:

Landscape architecture aims to provide physically and psychologically comfortable environment for people. In this respect, creating thermally comfortable areas is an important feature of landscape design and planning. Among the subjects that landscape architecture discipline interested are bioclimatic comfort and nature protection which are directly and strongly affected by the changes in climatic elements.

It was emphasized in the present study that climatic factors should be taken into account in the planning of cites and roads. The aim was to attract the attention of planners and designers to thermal comfort. SVF analysis shows that trees contribute to the sky openness.

SVF values change between 0.422 and 0.951 in the present study from the photos taken from the roads with plants, buildings and open sides. When the street widens SVF increases.

The largest SVF close to 1 was measured at Ata Botanical Garden in the city centre of Erzurum. This axis and its environment are rich in green area and trees.

Pedestrian walks should be evaluated in details for their security and comfort for liveable cities. In especially the cities like Erzurum, where cold and long winter conditions are prevalent, coniferous tress should not be used densely. They should be planted away from roads due to their lower branching characteristics and since they cause icing. Upper branching deciduous trees should be preferred since they offer shadow in summer and sunlight in winter.

Life quality can be increased through relocation, development and expansion of cities to comfortable areas or increasing comfort conditions in the areas with low comfortable conditions intervening them. Such a project to be carried out for Erzurum may serve as sample for new studies for other cold region cities.

References

Brown, M. J. ,Grimmond, C. S. B.,2001: Sky view factor measurements in downtown Salt Lake City: data report for the DOE CBNP URBAN Experiment October 2000. *Internal Report Los Alamos National Laboratory*, Los Alamos, New Mexico, LA-UR-01–1424, 16

Bulgan E., Yilmaz S., Matzarakis A., Irmak M.A., 2014: Quantification of summer thermal bioclimate of different land uses in an urban city centre. *Third International Conference on Countermeasures to Urban Heat Island, October* **13-15**, 523-534, Oral Presentation, Venezia, Italy

Correa E., Ruiz M.A., Canton A., Lesino G., 2012: Thermal comfort in forested urban canyons of low building density. An assessment for the city of Mendoza, Argentina. *Building and Environment*, **58**: 219-230

Fanger, P.O. 1970. Thermal comfort. Analysis and application in Environmental Engineering. *Danish Technical Press*, 244, Copenhagen.

Gomez, F., Montero, L., De Vicente, V., Sequi, A., Castilla, N.,2013: Vegetation influences on the human thermal comfort in outdoor spaces: criteria for urban planning. *The Sustainable City V.* P.13

Gulyas A., Unger. J, and Matzarakis A., 2006: Assessment of the microclimatic and human comfort conditions in a complex urban environment: modelling and measurements. *Building and Environment*, 41, 1713-1722

Gulten A., 2007: The investigation of relation between street and building geometry to benefit from solar radiation. Fırat University, Graduate School of Natural and Applied Sciences, Master thesis. 86p.

Herrmann J, Matzarakis A., 2012: Mean radiant temperature in idealized urban canyons—examples from Freiburg, Germany. *Int J. Biometeorol.,* **56**:199–203

Höppe, P. 1999: The physiological equivalent temperature - A universal index for the biometeorological assessment of the thermal environment. *İnternational Journal of Biometeorology*, 43(2), 71-75

İrmak MA., Yilmaz S., Yilmaz H., Ozer S., Toy S., 2013: Evaluation of different thermal conditions based on THİ under different kind of tree types – as a specific case in a Ata Botanic Garden in eastern Turkey. *Global NEST Journal*, **15**(1), 131-139

Kalnay, E., Cai M.,2003: "Impact of urbanization and land-use change on climate." *Nature* 423(6939): 528-531.

Lin T.P., Matzarakis A., Hwang R.L. 2010: Shading effect on long-term outdoor thermal comfort. *Building and Environment* ,**45**: 213–221

Matuscheck O., Matzarakis A., 2011: A mapping tool for climatological applications. *Meteorological Applications* **18**(2):230 - 237

Matzarakis A, Mayer H, İziomon M.G.,1999: Applications of a universal thermal index: physiological equivalent temperature**.** *İnternational Journal of Biometeorology*, **43**:76–84

Matzarakis, A., Rutz F., and Mayer H., 2010: Modelling Radiation fluxes in simple and complex environments–Basics of the RayMan model. *International Journal of Biometeorology*, **54**,131-139.

Oke, T.,1993: Boundary Layer Climates. 2nd edition. Cambridge: Cambridge University Press.

Oke, T.R., Johnson, D.G., Steyn, D.G., Watson, L.D., 1991: Simulation of surface urban heat island under ‘ideal’ conditions at night – Part 2: diagnosis and causation. Bound. Layer Meteor. 56, 339–358.

Souza, L., Rodrigues, D. S., Mendes, J. F. G., 2003: Sky View Factors Estimation Using A 3D-GIS Extension, Eighth International IBPSA Conferance, Eindhoven, Netherlands.

Ter Braak C.F. F., 1991: CANOCO-AFORTRAN program for Canonical Community ordination by (partial) (detrended) (canonical) Correspondence Analysis, Principle Component Analysis and Redundancy Analysis (Version 2.2). Technical Report LWA-88-02. *Agricultural Mathematics Group*, Holland

Watson, I. D., Johnson, G. T., 1988: Estimating Person View-Factors From Fish-Eye Lens Photographs, *International Journal of Bio-Meteorology*, **32**, 123-128.

Yan H., Fan S., Guo C.,Wu F., Zhang N., Dong L.,2014: Assessing the effects of landscape design parameters on intra-urban air temperature variability: The case of Beijing, China*, Building and Environment,* **76** : 44-53

Yavas M., Dursun D., Irmak MA., **Yilmaz S**., 2014: Links between Thermal Comfort and Street Design: The case of Erzurum City Centre. *Third International Conference on Countermeasures to Urban Heat Island*, 1202-1212, Oral Presentation, Venezia, Italy

Yilmaz S, Toy S, Irmak MA, Yilmaz H., 2007: Determination of climatic differences in three different land uses in the city of Erzurum, Turkey. *Building and Environment,* **42**(4), 1604-1612

Yilmaz, H., Toy S., Irmak M.A., Yılmaz S., Bulut Y., 2008: “Determination of temperature differences between asphalt concrete, soil and grass surfaces of the city of Erzurum, Turkey.” *Atmosfera.* 21 (2):135-146.

Yilmaz S., Toy S., Yilmaz H., 2010: Determination of the winter human thermal comfort distributions in a ski-centre. 7. BIOMET Conference 12- 14 April 2010 at the *Albert-Ludwigs-University Freiburg, Oral presentation, Germany, pp.* 370-373

Yilmaz S., Irmak, M.A., Matzarakis, A. 2013: The Importance of Thermal Comfort in Different Elevation for City Planning. *Global NEST Journal*, **15**(3): 408-420